Contents

Preface xv

Chapter 1 Introduction 1-1

1.0 Chapter 2—Planning Indirect Potable Reuse 1-2
1.1 Integrated Water Resources Management 1-3
1.2 Means of Introducing Reclaimed Water to Water Supplies 1-3
1.3 Institutional Considerations 1-4
1.4 Economics 1-4

2.0 Chapter 3—Health and Regulatory Considerations 1-4
2.1 Health Issues—Microorganisms 1-5
2.2 Chemical Constituents 1-6
2.3 Health and Regulatory Challenges 1-6

3.0 Chapter 4—Treatment Technology 1-7
3.1 Advanced Treatment 1-7
3.2 Natural Treatment Systems 1-9
3.3 Disinfection 1-10
3.4 Treatment Challenges 1-11

4.0 Chapter 5—System Reliability 1-11
4.1 Reliable Design and Operations 1-11
4.2 Ensuring Water Quality 1-14

5.0 Chapter 6—Addressing Public Perceptions 1-15

Chapter 2 Planning Indirect Potable Reuse 2-1

1.0 Introduction 2-2
2.0 Integrated Water Resources Planning 2-3
3.0 Means of Introducing Reclaimed Water to Potable Water Supplies 2-4
3.1 Groundwater Recharge 2-5
3.2 Existing Groundwater Recharge Facilities 2-10
3.3 Surface Water Augmentation 2-10
   3.3.1 Locations of the Delivery and Intake Points 2-10
   3.3.2 Volume of Water To Be Reused 2-12
   3.3.3 Character of Watershed 2-13
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 Regulations</td>
<td>2-13</td>
</tr>
<tr>
<td>4.1 Federal Regulations</td>
<td>2-13</td>
</tr>
<tr>
<td>4.2 State Regulations</td>
<td>2-15</td>
</tr>
<tr>
<td>4.3 Water Rights</td>
<td>2-15</td>
</tr>
<tr>
<td>4.3.1 Surface Water Doctrines</td>
<td>2-16</td>
</tr>
<tr>
<td>4.3.1.1 Appropriation Doctrine</td>
<td>2-16</td>
</tr>
<tr>
<td>4.3.1.2 Riparian Doctrine</td>
<td>2-17</td>
</tr>
<tr>
<td>4.3.1.3 Mixed or Hybrid Doctrines</td>
<td>2-17</td>
</tr>
<tr>
<td>4.3.2 Pueblo Rights</td>
<td>2-17</td>
</tr>
<tr>
<td>4.3.3 Groundwater Doctrines</td>
<td>2-18</td>
</tr>
<tr>
<td>5.0 Economics</td>
<td>2-18</td>
</tr>
<tr>
<td>5.1 Water-Quality Goals</td>
<td>2-18</td>
</tr>
<tr>
<td>5.2 Treatment Requirements</td>
<td>2-19</td>
</tr>
<tr>
<td>5.3 Costs of Facilities</td>
<td>2-20</td>
</tr>
<tr>
<td>6.0 Public Participation and Acceptance</td>
<td>2-20</td>
</tr>
<tr>
<td>7.0 References</td>
<td>2-22</td>
</tr>
<tr>
<td>8.0 Suggested Readings</td>
<td>2-23</td>
</tr>
</tbody>
</table>

**Chapter 3  Health and Regulatory Considerations**  

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>3-2</td>
</tr>
<tr>
<td>2.0 Health Issues</td>
<td>3-3</td>
</tr>
<tr>
<td>2.1 Microorganisms</td>
<td>3-3</td>
</tr>
<tr>
<td>2.1.1 Bacterial Pathogens</td>
<td>3-5</td>
</tr>
<tr>
<td>2.1.2 Protozoan Parasites</td>
<td>3-5</td>
</tr>
<tr>
<td>2.1.3 Viral Pathogens</td>
<td>3-6</td>
</tr>
<tr>
<td>2.2 Waterborne Illness</td>
<td>3-7</td>
</tr>
<tr>
<td>2.3 Chemical Constituents</td>
<td>3-9</td>
</tr>
<tr>
<td>2.3.1 Inorganics</td>
<td>3-10</td>
</tr>
<tr>
<td>2.3.2 Radionuclides</td>
<td>3-11</td>
</tr>
<tr>
<td>2.3.3 Organics</td>
<td>3-11</td>
</tr>
<tr>
<td>2.3.4 Microconstituents</td>
<td>3-13</td>
</tr>
<tr>
<td>2.4 Health-Effects Studies</td>
<td>3-16</td>
</tr>
<tr>
<td>2.5 Methods To Assess Health Effects and Relative Risk</td>
<td>3-9</td>
</tr>
<tr>
<td>2.5.1 Epidemiologic Investigations</td>
<td>3-9</td>
</tr>
<tr>
<td>2.5.1.1 Ecologic Studies</td>
<td>3-20</td>
</tr>
<tr>
<td>2.5.1.2 Surveillance Studies</td>
<td>3-21</td>
</tr>
<tr>
<td>2.5.1.3 Case-Control Studies</td>
<td>3-21</td>
</tr>
<tr>
<td>2.5.1.4 Cohort Studies</td>
<td>3-22</td>
</tr>
<tr>
<td>2.5.2 Chemical Risk Assessment</td>
<td>3-23</td>
</tr>
<tr>
<td>2.5.3 Microbial Risk Assessment</td>
<td>3-25</td>
</tr>
</tbody>
</table>
3.0 Water Quality Issues 3-26
  3.1 Water Quality Standards 3-26
  3.2 Discharge Permits 3-29
  3.3 Total Maximum Daily Loads 3-31
  3.4 Enforcement 3-32
4.0 Other Regulatory/Statutory Issues 3-32
  4.1 Water Rights 3-32
    4.1.1 Texas 3-32
    4.1.2 California 3-33
  4.2 Endangered and Threatened Species 3-33
5.0 State Regulations and Guidelines for Indirect Potable Reuse 3-34
  5.1 Regulations for Injection Wells 3-34
  5.2 State Regulations/Guidelines 3-35
    5.2.1 California 3-35
    5.2.2 Florida 3-37
    5.2.3 Hawaii 3-40
    5.2.4 Idaho 3-40
    5.2.5 Washington 3-41
  5.3 What To Do in the Absence of State Regulations/Guidelines 3-41
    5.3.1 Arizona 3-42
    5.3.2 Texas 3-44
    5.3.3 U.S. Environmental Protection Agency Guidelines 3-45
6.0 Recommendations 3-45
7.0 References 3-50
8.0 Suggested Readings 3-60

Chapter 4  Treatment Technology 4-1
1.0 Introduction 4-2
2.0 Advanced Treatment 4-3
  2.1 Biological and Chemical Nutrient Removal 4-5
  2.2 Coagulation/Flocculation and Solid–Liquid Separation 4-7
  2.3 Microfiltration and Ultrafiltration 4-8
  2.4 Ion Exchange 4-9
  2.5 Electrodialysis and Electrodialysis Reversal 4-10
  2.6 Reverse Osmosis and Nanofiltration 4-11
  2.7 Chemical Oxidation 4-14
  2.8 Advanced Oxidation Processes 4-15
Chapter 5  System Reliability

1.0 Introduction 5-2

2.0 Reliable Design and Operations 5-2

2.1 Treatment Facilities 5-2

2.1.1 Process and Equipment Redundancy 5-3

2.1.2 Piping and Pumping Flexibility 5-5

2.1.3 Disinfection 5-5

2.2 Emergency Storage or Discharge 5-6

2.3 Transmission and Conveyance 5-9

2.4 Reuse Facilities 5-9

2.4.1 Groundwater Recharge 5-9

2.4.2 Recharge System Reliability 5-10

2.4.3 Surface Water Replenishment 5-10

2.5 Instrumentation, Controls, and Alarms 5-10

2.6 Power Supply 5-11

2.7 Operations 5-12

2.7.1 Standard Operating Procedures 5-13

2.7.2 Cross-Training 5-15

2.7.3 Emergency Response 5-16

3.0 Ensuring Water Quality 5-17

3.1 Regulatory and Performance Compliance 5-17

3.2 Performance Contingencies 5-20

3.3 Contingency Planning 5-21

4.0 Regulator Participation 5-22

4.1 Project Development Phase 5-22
6.0 Summary of Project Case Studies 6-15

6.1 Investing in Water Reliability 6-15

6.1.1 Water Resources Recovery Project (Tampa, Florida) 6-15

6.1.2 Water Repurification Project (San Diego, California) 6-16

6.1.3 Clean Water Revival Project (Dublin San Ramon, California) 6-16

6.1.4 Water Campus (Scottsdale, Arizona) 6-16

6.1.5 Groundwater Replenishment System (Orange County, California) 6-17

6.2 Creating Water-Quality Confidence 6-17

6.2.1 Water Repurification Project (San Diego, California) 6-18

6.2.2 Clean Water Revival Project (Dublin San Ramon, California) 6-18

6.2.3 Water Resources Recovery Project (Tampa, Florida) 6-18

6.2.4 Water Campus (Scottsdale, Arizona) 6-19

6.2.5 Groundwater Replenishment System (Orange County, California) 6-19

6.2.6 Upper Occoquan Sewage Authority (Virginia) 6-20

6.3 Turning Conflict and Opposition Into Assets 6-20

6.3.1 Water Repurification Project (San Diego, California) 6-20

6.3.2 Upper Occoquan Sewage Authority (Virginia) 6-21

6.3.3 Water Campus (Scottsdale, Arizona) 6-21

6.3.4 Clean Water Revival Project (Dublin San Ramon, California) 6-21

6.3.5 Groundwater Replenishment System (Orange County, California) 6-22

6.4 Ensuring a Good Policy Decision 6-22

6.4.1 Groundwater Replenishment System (Orange County, California) 6-22

6.4.2 Water Campus (Scottsdale, Arizona) 6-23

6.4.3 Water Repurification Project (San Diego, California) 6-23

6.4.4 Clean Water Revival Project (Dublin San Ramon, California) 6-24